R58-44

Reprinted from METABOLISM
Vol. VII, No. 2, March, 1958
Printed in U.S.A.

Caloric Intake During Prolonged Cold Exposure

By P. F. IAMPIETRO, D. E. BASS AND E. R. BUSKIRK

IT IS generally believed that living in cold regions, e.g., subarctic or arctic, is associated with caloric intakes which are greater than those observed in more temperate climates. Thus, Johnson and Kark[1] reported that men living in the subarctic (mean ambient temperature -30 F. (-34 C.)) consumed up to 5000 Calories (kilocalories) daily as compared with daily intakes of 3000 Calories in hot environments.

However, recent work has indicated that climate per se has little influence on the caloric intake of soldiers in the field.[2,3] In these studies, a group of men living in the subarctic was compared with a group performing similar daily activities in a desert environment. It was found that although the group in the Arctic consumed from 600 to 800 Calories per day more than the desert group, the higher caloric intake in the subarctic appeared to be related to a greater energy expenditure; this was due largely to the encumbrance of arctic clothing and differences in terrain and ground cover over which the men walked, rather than to an effect of cold. It was found that resting oxygen consumption ($\dot{V}_{O_2}$), measured in comfortable ambient conditions during the course of the day, was not influenced by climate, i.e., $\dot{V}_{O_2}$ was similar in both climates.

The assessment of caloric requirements for cold climates is not a simple problem. It is impossible in a field situation to distinguish the impact of cold stress from the effects of the heavy, cumbersome clothing which must necessarily be worn. In addition, the microclimate to which the individual's body is exposed often bears no relationship to the ambient environment. The present study was designed to eliminate clothing and activity as variables, in order to obtain information concerning the effects of cold stress per se on caloric intake.

METHODS

Five men lived in a room at 60 F. (15.6 C.) for two weeks, without clothing except for cotton shorts, and were allowed only minimal activity, e.g., playing cards, reading, writing, watching TV or movies. Windspeed was less than one mph and relative humidity was 50 per cent. The two weeks at 60 F. were preceded and followed by two weeks at 80 F. (26.7 C.) During the cold period, each subject was allowed one woolen Army blanket at night. Activity and dietary compositions were the same for all periods. The diet contained the following items: (a) a high calorie, chocolate flavored milk drink, (b) bread and butter, (c) starch jelly bar and (d) jam. In addition, black coffee was given at each meal and a multivitamin supplement was given morning and evening. All items, except the milk drink, were allowed *ad libitum* at meal times. Accurate records were kept of the amount of each component eaten and caloric intakes were calculated from these records.

Resting oxygen consumption ($\dot{V}_{O_2}$) was measured at intervals during the day with a

---

From the Physiology Branch, Quartermaster Research and Development Center, Natick, Massachusetts.
We thank Drs. M. Mager and H. Spector for their cooperation in carrying out this study.
Received for publication Feb. 2, 1957.

Sanborn Waterless Metabulator. These values were used to calculate energy expenditure. Nude body weights were measured each morning after the subject had voided.

Results

For the purposes of this paper, the first week of the control period will be disregarded, since this was a transition period between a conventional diet and the one used in this study. Caloric intake during the second week of the control period averaged 2287 Calories/man/day (fig. 1); the daily individual intake ranged from 1589 to 2514 Calories. Body weight loss during the same period averaged 1.75 Kg./man (fig. 2).

During the cold period caloric intake increased. The mean daily intake was 2870 Calories/man; the daily individual intake ranged from 1831 to 4178 Calories. There was no change in mean body weight during this period; mean body weights on the first and last day of the cold period were 67.83 and 67.76 Kg., respectively.

During the recovery period caloric intake again fell off. The mean daily intake was 2405 Calories/man; the daily individual intake ranged from 1146 to 3237 Calories. Body weight decreased an average of 0.9 Kg./man during the recovery period. Thus, the men ingested an average of 525 Calories/man/day more in the cold than in the control and recovery periods.

Energy expenditure was calculated for the 12 hours of the day covered by measurements of $\dot{V}_{O_2}$. These calculations do not include the extra energy ex-

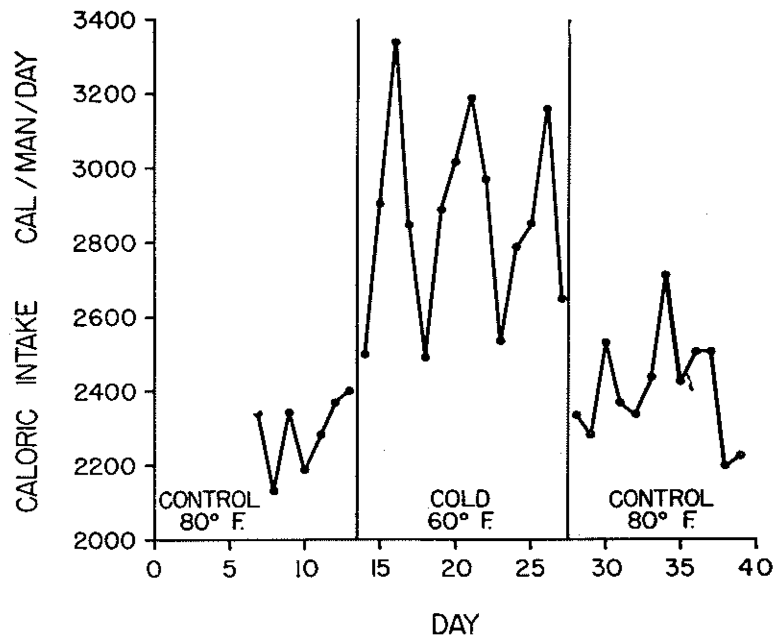

Fig. 1.— Daily caloric intake. Points represent the means of five men.

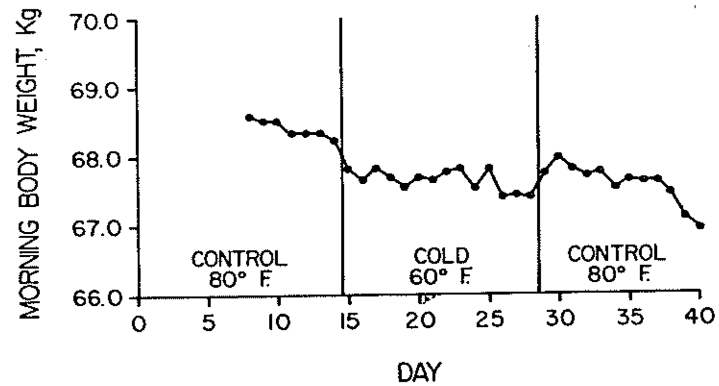

Fig. 2.—Morning body weight. Points represent the means of five men.

penditure above resting, e.g., eating (specific dynamic action peaks) and performing ablutions. Table 1 shows that resting energy expenditures during the day in the control, cold and recovery periods were 894, 1030 and 885 Calories/man/day, respectively. There was, therefore, an average increase of 140 Calories per day in the cold period.

In order to estimate caloric turnover a correction must be applied for the caloric equivalent of any weight changes which occur during an experimental period. Such corrections were made for the weight lost during the control and recovery periods; since there was essentially no weight change in the cold, no correction was applied to the observed caloric intake during that period. The caloric equivalent for weight loss has been taken as 3.5 Calories per gram; this represents an average of values cited by others.[2, 4, 5] The corrected caloric intake was calculated for the last seven days of the control period and for all days of the recovery period. When caloric intakes are thus corrected, the intakes for the control and recovery periods were 2661 and 2678 Calories/man/day, respectively (table 1). The corrected change in caloric intake between control-recovery and cold periods is, therefore, 200 Calories, which agrees well with the results obtained from $\dot{V}_{O_2}$ measurement.

Table 1.—*Summary of Caloric Intake and Energy Expenditure*

	Period		
	Control	Cold	Recovery
Caloric Intake (Calories/man/day)	2287	2870	2405
Weight Loss (Gm./man/day)	107	0	78
Caloric Equivalent of Weight Loss (Calories/man/day)	374	0	273
Corrected Caloric Intake (Calories/man/day)	2661	2870	2678
Resting Energy Expenditure during 12 Daytime Hours (Calories/man)	894	1030	885

Discussion

It might appear, at first glance, that exposure to a temperature of 60 F. is not a severe cold stress. However, experience in this laboratory has shown that when nude and sedentary men are exposed to this temperature for a prolonged period of time, there is marked subjective discomfort and mean skin temperature may fall as much as 7 F. below that observed at 78 to 80 F. Prolonged chilling of this degree may be much more severe than that experienced under most conditions in the subarctic, where men are warmly dressed when outdoors and are exposed to cold for only short periods of time.[2, 6] Therefore, it appeared likely that effects of cold stress per se on caloric intake should be revealed in the present study. It is recognized that more severe chilling would probably cause a greater increase in energy expenditure and caloric intake than was observed in this study. However, it is questionable whether appreciably greater cold stress could be tolerated for prolonged periods.

From the results presented here it would appear that the increased caloric intake in the cold is associated with the measured increase in resting $\dot{V}_{O_2}$ (table 1), the latter probably being the result of increased muscle activity, e.g., nondetectable shivering and occasional frank shivering. Although the increase in $\dot{V}_{O_2}$ was based on measurements obtained only during the 12 daytime hours, it is likely that this increase, 140 Calories/man, represents the total difference for the entire 24 hour period. Since the men slept comfortably under a blanket at night, $\dot{V}_{O_2}$ during these hours was probably not different from corresponding hours of the control period.

The data of Johnson and Kark[1] indicate that for every degree F. fall in mean ambient temperature there is a 20 Calorie increase in daily caloric intake. In the present study the uncorrected caloric intake data show a difference of 525 Calories for a 20 degree drop in temperature (26 Calories/°F.). However, when caloric intake is "corrected" for weight loss this value becomes 200 Calories (10 Calories/°F). In comparing our findings with the above authors, the following points must be borne in mind: (a) their caloric intakes were not corrected for any weight changes which may have occurred; (b) physical activity was not well defined; (c) caloric intake was assessed by the mess inventory method.

The results of the present study, performed under laboratory conditions, support the recent findings from this laboratory[2, 3] that when similar daily activities are performed, the major difference in caloric intake between subarctic and desert environments is due mainly to the higher energy cost imposed by the cumbersome arctic clothing worn in cold regions.

Summary

The effects of continuous cold stress on caloric intake and energy expenditure were studied on five men. Cold stress consisted in living in a chamber at 60 F. (15.6 C.) for 14 days. The men wore only shorts and were allowed minimal physical activity. The cold period was preceded and followed by two weeks at 80 F. (26.7 C). Activity and dietary composition were the same for all periods.

During the control and recovery periods caloric intake averaged 2287 and 2405 Calories/man/day and weight loss averaged 1.75 and 0.90 Kg./man, respectively.

During the cold period caloric intake was 2870 Calories/man/day; there was no weight loss.

When corrected for weight loss, caloric intakes averaged 2661 and 2678 Calories/man/day for the control and recovery periods, respectively. An increase in resting energy expenditure of 140 Calories/man/12 daytime hours was observed in the cold. The increased caloric intake in the cold was associated with an increased energy expenditure due to nondetectable shivering and occasional frank shivering. There was no evidence that cold stress imposed additional caloric requirements apart from those resulting from increased muscle activity.

References

1 Johnson, R. E., and Kark, R. M.: Environment and food intake in man. Science *105:* 378, 1947.

2 Buskirk, E. R., Kreider, M., Brebbia. R., Morana, N., Daniels, F., Jr., and Welch, B. E.; Mann, J. B., Insull, W., Jr. and Friedemann, T. E.: Caloric intake and energy expenditure in a subarctic environment. Technical Report EP-33, QM Research and Development Center, 1956 *and* Medical Nutrition Laboratory Report No. 173, December 1955.

3 Iampietro, P. F., Vaughan, J. A., MacLeod, A. R., and Welch, B. E.; Marcinek, J. G., Mann, J. B., Grotheer, M. P., and Friedemann, T. E.: Technical Report EP-40, QM Research and Development Center, 1956 *and* Medical Nutrition Laboratory Report No. 190, 1956.

4 Dole, V. P., Schwartz, I. L. Thorn, N. A., and Silver, L.: The caloric value of labile body tissue in obese subjects. J. Clin. Invest. *34:* 590-594, 1955.

5 Grande, F., Keys, A., Brozek, J., Anderson, J. J. and Taylor, H. L.: Unpublished data from 1954 survival ration study, University of Minnesota.

6 Bly, C. G., Johnson, R. E., Kark, R. M., Consolazio, C. F., Swain, H. L., Laudani, A., Maloney, M. A., Figueroa, W. G., Imperiale, L. E.: Survival in the cold. U.S. Armed Forces Med. J. *1:* 615, 1950.

7 Iampietro, P. F., Bass, D. E., and Buskirk, E. R.: Diurnal oxygen consumption and rectal temperature of man during continuous cold exposure. J. Applied Physiol. *10:* 398, 1957.